CHAPTER 2

Classification of materials

2.1 Introduction

The universe is made up of very large number of substances. If this vast array of substance is examined more closely, it is found that they are made up of some basic substances which were given the name elements and compounds.

As we all know that elements, compounds and mixtures are combinedly known as matter.

All the matter around us is not pure. In fact, matter around us is of two types:

(i) Pure substance and

(ii) Mixtures

Let us now discuss, pure substances and mixtures in little more detail.

2.2 Pure substances

A pure substance is made up of only one kind of particles. These particles may be either atoms or molecules. Thus, **A pure substance may also be defined as a material which contains only one kind of atoms or molecules.**

Based upon the nature of the constituent particle pure substance is of two types, i.e., elements and compounds.

A pure substance which is made up of only one kind of atom is called an element while that which is made up of only one kind of molecule is called a compound.

A pure substance is uniform or homogenous throughout because it consists of only one kind of particles. These particles are similar to one another and cannot be separated into simpler particles by any physical process.

For example, water is a pure substance because it has uniform composition throughout. It consists of only one kind of particles called water molecules which cannot be separated into its constituents (hydrogen and oxygen) by any simple physical process.

2.3 Impure substances - mixtures

A mixture is a material which contains two or more different kinds of particles (atoms or molecules) which do not react chemically but are physically mixed together in any proportion. Thus, mixture are impure substances. The pure substances present in a mixture are called the components or the constituents of the mixture. For example, if we dissolve some common salt (sodium chloride) in water, both of which are pure substances, the solution of common salt in water is known as a mixture. It has been obtained by simple mixing of common salt and water without any chemical reaction.

A mixture has a variable composition, i.e., does not have a fixed composition. Therefore, no definite formula can be given to a mixture. Along with this, a mixture does not have a fixed melting point or a fixed boiling point.

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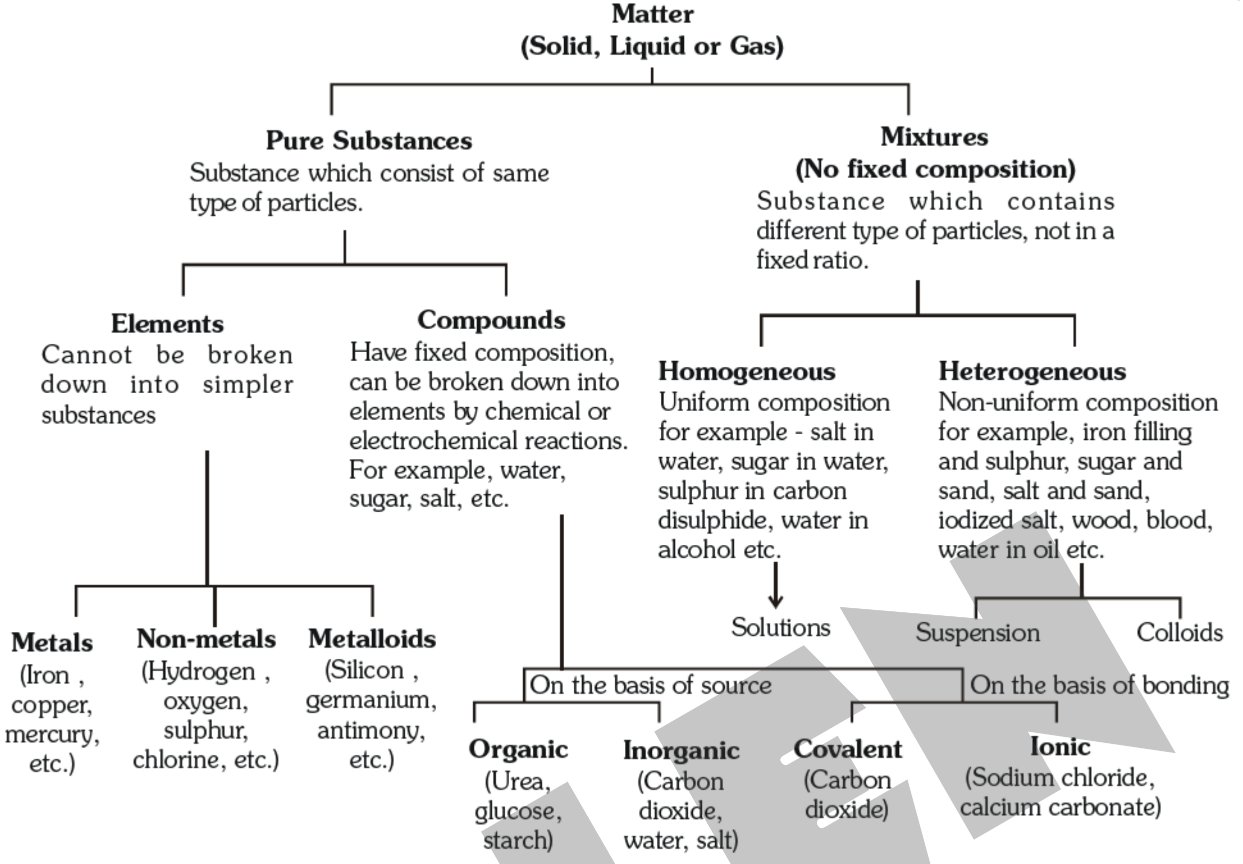
Matter
(Solid, Liquid or Gas)
Pure Substances
Substance which consist of same type of particles.
Mixtures
(No fixed composition)
Substance which contains different type of particles, not in a fixed ratio.
Elements
Cannot be broken down into simpler substances
Compounds
Have fixed composition, can be broken down into elements by chemical or electrochemical reactions. For example, water, sugar, salt, etc.
Homogeneous
Uniform composition for example - salt in water, sugar in water, sulphur in carbon disulphide, water in alcohol etc.
Heterogeneous
Non-uniform composition for example, iron filling and sulphur, sugar and sand, salt and sand, iodized salt, wood, blood, water in oil etc.
Solutions
Suspension
Colloids
Metals
(Iron , copper, mercury, etc.)
Non-metals
(Hydrogen , oxygen, sulphur, chlorine, etc.)
Metalloids
(Silicon , germanium, antimony, etc.)
On the basis of source
On the basis of bonding
Organic
(Urea, glucose, starch)
Inorganic
(Carbon dioxide, water, salt)
Covalent
(Carbon dioxide)
Ionic
(Sodium chloride, calcium carbonate)

CONCEPTUAL CHALLENGE 2.1

Why are composite materials often used instead of single material?

Explanation

Composite material are those that combine the properties of two constituents. In order to get the exact properties needed for particular job. For example,

(a) Steel: It is used to make rust free, unbreakable utensils.

(b) Bone is composite material.

(c) Wood consists of cellulose mixed with **'Lignin'** which is largely responsible for the strength of the wood.

2.4 Elements

Robert Boyle was the first scientist who used the term element in 1661. Antoine Laurent Lavoisier (1743-1794), a French chemist was the first to give a useful definition of an element as follows.

An element is defined as the simplest form or the basic form of a pure substance which can neither be broken into nor built up from simpler substances by any physical or chemical method. For example, iron is an element because we may break it into pieces, as small as possible, but the chemical formula of all pieces will be same as that of iron.

This definition given above is not considered to be absolutely correct now a days. This is because after the discovery of radioactivity, it has been found that elements can be broken into simpler substance. Furthermore, a number of elements have been synthesized from simpler substances. Hence, the definition of an element has been modified as follows.

An element is now defined as a pure substance that contains only one kind of atoms.

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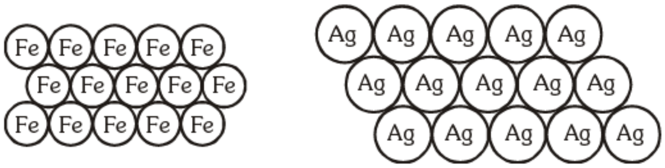

Elements (a) Iron (b) Silver

An element is made up of only one kind of atoms which are identical in all respects, size, mass, composition, etc. However, atoms of different elements differ in size, mass and composition.

118 Elements have been discovered so far. Out of these, 90 elements have been found to occur in nature whereas the remaining 28 have been synthesized by the scientists in the laboratories by suitable chemical reactions and nuclear reactions.

Further, elements are found to exist in all the three states of matter.

Solid elements

Majority of the elements are solids at room temperature. For example, iron, copper, aluminium, silver, gold, sodium, potassium, sulphur, phosphorus, carbon (graphite or diamond), iodine, etc.

Liquid elements

Mercury and bromine are the only two elements which are known to exists in the liquid state at room temperature. Gallium and caesium become liquid at a temperature slightly above room temperature (303 K).

Gaseous elements

Eleven elements are gaseous at room temperature. These are hydrogen, oxygen, nitrogen, fluorine, chlorine, helium, neon, argon, krypton, xenon and radon.

2.5 Classification of elements

Classification of elements based on physical and chemical properties

On the basis of physical properties, elements have been divided into the following three types:

(i) Metals (ii) Non-metals and (iii) Metalloids.

Physical properties of metals

Some important physical properties of metals are described below:

(1) Metals are malleable

This means that metals can be hammered or beaten to form thin sheets without breaking. However, all metals are not equally malleable. Some are more malleable than others. For example, gold and silver are the most malleable metals.

Uses

(i) Silver foil is used for decorating sweets.

(ii) Aluminium foils are used for wrapping medicines, cigarettes and food items like biscuits, chocolates, etc. Milk bottle caps are also made up of aluminium foil.

(iii) Sheets of iron, copper, aluminium, etc. are used for making utensils, containers and bodies of automobiles.

(2) Metals are ductile

This means that metals can be drawn to stretched into thin wires. Like malleability, all the metals are not equally ductile. Gold and silver are the most ductile metals. Gold is so ductile that 1 gram of it can be drawn to form a wire of about 2 kilometer length.

(3) Metals are good conductors of heat and electricity

Generally, metals are good conductors of heat, i.e., they have high thermal conductivity. After silver, copper is the best conductor of heat. The cooking utensils and water boilers, etc. are usually made up of copper or aluminium metals because they are very good conductors of heat. Among metals, lead is the poorest conductor of heat.

Metals are good conductors of electricity also. That is metals offer very little resistance to the flow of electric current and hence show high electrical conductivity. Silver is the best conductor of electricity followed by copper, gold, aluminium and tungsten.

The metals like lead and mercury offer very high resistance to the flow of electric current and hence are poor conductor of electricity.

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(4) Metals are lustrous

Due to their shining surface, metals are good reflectors. Silver metal is an excellent reflector of light and hence is used for silvering of mirrors.

(5) Metals are generally hard

Metals are generally quite hard. For example, iron, aluminium, copper, etc. are very hard and hence cannot be cut with a knife. However, metals like sodium and potassium are quite soft and hence can be easily cut with a knife.

(6) Metals have high tensile strength

Metals have a high tensile strength. This means that metals can hold large weights without breaking. For example, steel (which is an alloy of iron and carbon) is very strong and hence has a high tensile strength. Due to this, it is used for construction of buildings, bridges, railway lines, chains, girders, machines, vehicles etc. Although most of the metals are strong, yet some of the metals are not strong. For example, sodium and potassium metals are not strong and hence have low tensile strength.

(7) Metals are solids at room temperature

Except mercury which is a liquid at room temperature.

(8) Metals generally have high melting and boiling points

However, sodium and potassium have low melting points; sodium = 371 K, potassium = 336 K, gallium and cesium become liquid at temperature slightly above room temperature (303 K).

(9) Metals generally have high densities

Except sodium and potassium which have low densities.

(10) Metals are sonorous

This means that metals make a ringing sound when hit. It is because of this property that metals are used for making bells, cymbals (manjira – in Hindi) and wires of violin, guitar, sitar, tanpoora, etc.

Physical properties of non-metals

The physical properties of non-metals are just opposite to those of metals. Some of these properties are described below:

(1) Non-metals are not malleable but are brittle (break easily)

This means that non-metals cannot be hammered or beaten to form thin sheet.

(2) Non-metals are not ductile

This means that non-metals cannot be drawn or stretched into wires.

(3) Non-metals are bad conductors of heat and electricity

This means that non-metals do not allow heat and electricity to pass through them. Therefore, non-metals act as **insulators**. However, there are some exceptions.

For example, diamond is an allotropic form of carbon. It is a non-metal which is a good conductor of heat but bad conductor of electricity. Graphite is another allotropic form of carbon. It is also a non-metal but is a good conductor of heat and electricity. Therefore, graphite is used for making electrodes of batteries and dry cells.

(4) Non-metals are not lustrous but actually have dull appearance

However, iodine and graphite are exceptions. They are non-metals which have shining surface like that of metals.

(5) Non-metals are generally soft

Except diamond which is extremely hard. Diamond which is an allotropic form of carbon is the hardest natural substance known.

(6) Non-metals are not strong

Non-metals have low tensile strength.

(7) Non-metals may be solid, liquid or gases at room temperature

Non-metals exist in all the three states of matter i.e. solid, liquid and gas. For example, boron, carbon, sulphur and phosphorus are solid non-metals, bromine is a liquid non-metal while hydrogen, oxygen, nitrogen and chlorine are gaseous non-metals.

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(8) Solid non-metals have comparatively low melting and boiling points

Except boron, graphite and diamond which have high melting and boiling points.

(9) Non-metals have low densities

Non-metals are generally light elements. That is why have low densities. For example, density of sulphur is 2 g/cm^3.

(10) Non-metals exist in different colours

For example, sulphur is yellow, phosphorus is white, yellow or red, graphite is black, chlorine is yellowish green, bromine is reddish brown while hydrogen, oxygen, nitrogen are colourless.

(11) Non-metals are not sonorous

Metalloids

Elements which have properties in between those of metals and non-metals are called **metalloids or semimetals**. For example, Boron(B), Silicon (Si), Germanium (Ge), Arsenic (As), Antimony (Sb), Tellurium (Te), Astatine(At) and Polonium(Po).

These elements show some properties of metals and other properties of non-metals. For example, they may look like metals but are brittle like non-metals. They are neither good conductors of electricity nor insulators like non-metals. They are generally **semi-conductors**.

2.6 Mixture

Most of the matter around us is not pure but is actually a mixture of two or more pure substances. For example, air is not a pure substance but is a mixture of gases such as oxygen, nitrogen, inert gases (mainly argon), carbon dioxide, water vapours, etc. Milk is also not a pure substance because it is a mixture of water, fat and proteins.

Types of mixtures

Depending upon the nature of components that are mixed to form mixtures, mixtures have been classified into the following two types:

(1) Homogeneous mixtures **(2) Heterogeneous mixtures**

(1) Homogeneous mixtures

A homogeneous mixture has a uniform composition throughout. The components of a homogeneous mixture are not visible to the naked eye nor even under a microscope. There are no visible boundaries of separation between the components of a homogeneous mixture. In other words, a homogeneous mixture consists of only one phase. The single phase of the homogeneous mixture may be a liquid, gas or solid. For example,

(i) A solution of sugar in water is a homogeneous mixture in the liquid phase.

(ii) A mixture of two or more miscible liquids is also a homogeneous mixture in the liquid phase. For example, a solution of alcohol and water is a homogeneous mixture.

(iii) Alloys are homogeneous mixtures of two or more metals in the solid phase. For example, brass is an alloy of zinc and copper and steel is an alloy of iron (98%), carbon (1.5%) and other metals (0.5%).

Note that all homogeneous mixtures are called solutions.

(2) Heterogeneous mixtures

A heterogeneous mixture does not have a uniform composition throughout. The components of a heterogeneous mixture are either visible to the naked eye or under a microscope. Therefore, there are visible boundaries of separation between the components of a heterogeneous mixture. In other words, heterogeneous mixtures have two or more distinct phases. For example,

(i) A mixture of sugar and sand is a heterogeneous mixture because different parts of the mixture will have different sugar-sand compositions.

(ii) Iodized salt

(iii) Gun powder (sulphur + charcoal + KNO_3)

(iv) A suspension of solids in liquids is a heterogeneous mixture. For example, a suspension of chalk or sand particles in water is a heterogeneous mixture.

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2.7 Compounds

A compound is defined as a pure substance made up of two or more elements chemically combined together in a fixed proportion by mass.

Water (H_2O) is a compound made up of two elements, hydrogen (H) and oxygen (O), chemically combined together in a fixed proportion of 1: 8 by mass.

Other examples of compounds are methane (CH_4), silica or sand (SiO_2), ammonia (NH_3), ammonium chloride (NH_4Cl), caustic soda (NaOH), washing soda (Na_2CO_3), lime or quick lime or calcium oxide (CaO), slaked lime or calcium hydroxide [$Ca(OH)_2$], potassium nitrate (KNO_3), copper sulphate ($CuSO_4$), potassium sulphate (K_2SO_4), potassium permanganate ($KMnO_4$), iron sulphide (FeS), hydrogen chloride or hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3), glucose ($C_6H_{12}O_6$), sugar or cane-sugar or sucrose ($C_{12}H_{22}O_{11}$), etc.

Properties of compounds

(1) A compound is made up of the different elements combined together in a fixed proportion by mass.

(2) A chemical compound is formed as a result of a chemical change (or reaction) and its properties are entirely different from those of its constituents. A chemical compound cannot be formed simply by mixing constituent elements. It is formed only when a chemical reaction takes place between them. For example, simply by mixing iron filings and sulphur powder, we get a mixture whose properties are the same as those of its constituents. However, when this mixture is heated strongly a chemical reaction occurs and a new compound called iron sulphide is formed.

$$8Fe + S_8 \xrightarrow{\text{Strongly heat}} 8FeS$$

Iron	Sulphur	Iron sulphide
(Element)	(Element)	(Compound)

The properties of iron sulphide thus formed are altogether different from those of its constituents, i.e. iron and sulphur. For example, when dilute sulphuric acid is added to iron sulphide, a foul smelling gas (having the smell of rotten eggs) called hydrogen sulphide (H_2S) is evolved.

However, when iron reacts with dilute sulphuric acid, hydrogen gas is formed which is a colourless, odourless combustible gas. This means that iron sulphide does not show the properties of iron present in it.

Similarly, water is not formed when hydrogen and oxygen are simply mixed together. It is formed only when an electric spark is passed through this mixture. The properties of water thus formed are altogether different from those of its constituent elements. For example, hydrogen is a combustible gas while oxygen is a supporter of combustion. Water on the other hand is neither combustible nor a supporter of combustion, it actually extinguishes the fire.

(3) A compound cannot be separated into its constituents by simple physical means.

For example, water cannot be separated into its constituents i.e. hydrogen and oxygen elements by simple physical means such as filtration, evaporation, distillation, solvent extraction, or using a magnet. This separation can however, be done by chemical means i.e. by electrolysis (or passing electricity)

(4) A compound has a definite molecular formula and fixed melting point and boiling point.

(5) Energy in form of heat or light is usually evolved or absorbed when a compound is formed.

For example, formation of carbon dioxide (CO_2) by burning of coke in air or oxygen is always accompanied by evolution of heat.

(6) A compound is a homogeneous substance.

For example, if we take water in a glass or a beaker, every drop of it looks alike i.e. it is homogeneous and will show the same properties.

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Important note

1. **Compounds are homogeneous but mixtures may be homogeneous or heterogeneous.**

Homogeneity alone cannot be used to decide between a mixture and a compound. For example, solutions of common salt, sugar, copper sulphate, etc. in water are homogeneous. But still they are regarded as mixtures because of the following reasons:

(i) The common salt solution shows the properties of its constituents i.e. common salt and water.

(ii) The constituents of the salt solution i.e. common salt and water can be separated by the physical process of distillation.

(iii) The composition of the salt solution is variable. In other words, different amounts of salt can be dissolved in the same amount of water to get solutions having different compositions. Thus, a salt solution does not have a definite formula.

(iv) Salt solution does not have a fixed boiling point.

2. **Non-stoichiometric compounds**

Molecules (constituting units of compounds) which have definite atomic composition are referred as stoichiometric compounds. For example, CH_4, H_2O, NH_3, etc.

Certain materials in which atomic composition is variable are called non-stoichiometric compounds. For example, the composition of cuprous sulphide may vary from $Cu_{1.7}S$ to Cu_2S.

Non-stoichiometry is common feature of sulphides and oxides of transition metals.

Types of compounds

All the compounds may be divided into the following two categories:

(1) Organic compounds

(2) Inorganic compounds

Organic compounds are the compounds containing carbon and a few other elements like hydrogen, oxygen, nitrogen, sulphur, halogens, etc. These were originally obtained only from animals and plants.

Inorganic compounds are the compounds containing any two or more elements out of more than 118 elements known so far. These are usually obtained from minerals and rocks.

Criteria of purity of compounds

A solid compound is said to be pure if it has a sharp melting point i.e. whole of the solid melts within a range of 0.5°C or 0.5 K. Impure solids on the other hand have lower melting points than the pure solids because impurities lower or depress the melting points.

A liquid compound is said to be pure if it has a fixed boiling point i.e. whole of the liquid distills at a fixed temperature.

Impure liquids on the other hand have higher boiling points than the pure liquids. This is because impurities always raise the boiling points. For example, pure water boils at $100\ ^0C$ (373K) at one atmosphere pressure. However, sea water is impure because it contains a number of dissolved salts. Thus, the boiling point of sea water is always higher than 100^0C (373 K).

CONCEPTUAL CHALLENGE 2.2

List the following 'waters' in order of increasing purity:

Ocean water, rainwater and drinking water.

Explanation

Ocean water is the least pure because it contains a large amount of dissolved compounds. That is why it is not drinkable and cannot be used for crop irrigation. Drinking water also contains chlorine and some dissolved compounds but not nearly as much as ocean water. Rain water is the purest of three but still contains some dissolved gases from the air.

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2.8 Solutions

A solution is defined as a homogeneous mixture of two or more chemically non-reacting substances whose composition can be varied within limits.

It may be noted that all mixtures are not solutions. If a mixture is to be called as solution, then it must satisfy the following two conditions:

(i) The components of a mixture should be non-reacting.

(ii) Mixture should be homogeneous.

For example, homogeneous mixture from our daily life is vinegar which is a 5-8% solution of acetic acid in water.

Aqueous and non-aqueous solutions

Most of the substances are soluble in water. That is why water is sometimes called a universal solvent.

A solution in which water acts as the solvent is called an aqueous solution while the one in which any other liquid acts as the solvent is called a non-aqueous solution. For example, the solution of common salt or sugar in water is called an aqueous solution. However, solution of bromine in carbon tetrachloride, sulphur in carbon disulphide, iodine in alcohol (tincture of iodine) are called non-aqueous solutions.

2.9 Methods of expressing concentration of solutions

Following are the various ways of expressing concentration of solutions.

1. Mass percent
2. Volume percent
3. Normality
4. Molarity
5. Molality
6. Mole fraction
7. Mass fraction
8. Formality
9. Mole percent

(1) Mass percent (% by weight)

The mass of solute in grams present in 100g of the solution is termed as the mass percent.

Mathematically,

$$\%\text{ by weight} = \frac{\text{Weight of the solute}}{\text{Weight of the solution}} \times 100 \text{ or mass } \% = \frac{\text{mass of the solute}}{\text{mass of solution}} \times 100$$

For example, a 15% solution of urea in water (by mass) means that 15 g of urea is present in 100 g of solution. Similarly, a 10% solution of NaCl by weight means that 100g of solution contains 10 g of NaCl.

CONCEPTUAL CHALLENGE 2.3

A syrup is prepared by dissolving 250 gram of sucrose in 150 gram of water. Calculate the mass percent sucrose in the solution.

Explanation

We know that

$$\text{Mass\%} = \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

However, Mass of solution = Mass of solute + Mass of solvent = 250 + 150 = 400 g

$$\text{Mass\%} = \frac{250\text{g} \times 100}{400\text{g}} = 62.5\%$$

(2) Volume percentage (% by volume)

It may be defined as the volume of solute in ml present in 100 ml of the solution.

$$\%\text{ by volume} = \frac{\text{Volume of the solute}}{\text{Volume of the solution}} \times 100$$

For example, a 20% solution of acetic acid (by volume) means 20 ml of acetic acid is present in 100 ml of solution.

Find the volume percentage of a solution, in which 20 ml of acetic acid is dissolved in 100 ml of solution?

$$\%\text{ by volume} = \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100 = \frac{20}{100} \times 100 = 20\%$$

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2.10 Solubility

Solubility

The maximum amount of solute in grams which can be dissolved in 100 grams of the solvent at a given temperature to form a saturated solution is called the solubility of the solute in that solvent at that particular temperature.

For example,

A maximum of 36 grams of common salt (sodium chloride) can be dissolved in 100 grams of water at 20^0C (or 293 K) , therefore, the solubility of common salt in water at 20 ^{0}C (or 293 K) is 36 grams.

Various factors that effect solubility

(i) Effect of temperature

Most solids and liquids are more soluble in water at higher temperatures. Unlike solids, gases become less soluble as the temperature increases. This can be witnessed by observing water being heated. As the temperature increases, the water tends to fizz somewhat as the dissolved gases are expelled.

CONCEPTUAL CHALLENGE 2.4

How high temperature in lakes could be a problem for aquatic life?

Explanation

High temperature in lakes can be a danger for aquatic animals and may cause fish kills. The lower solubility of oxygen at the higher temperatures can lead to an oxygen-depleted lake.

(ii) Effect of pressure

Solubility also depends on pressure. When you increase the pressure, you can usually dissolve more gases in the liquid. Think about your soda can. They are able to keep the fizz inside because the contents of the can are under higher pressure.

(iii) Nature of solvent

Solvents with high value of dielectric constant can dissolve polar ionic compounds to a larger extent than the solvents with low value of dielectric constants.

(iv) Nature of solute

Ionic compounds (or polar compound) are more soluble in water (i.e., a polar solvent). Non-polar compounds are more soluble in non-polar solvents like benzene. [Like dissolves like]

(v) Size of solute particles

Smaller the size of the particles greater is the solubility. For example, it is easier to dissolve powdered sugar than granules of sugar. Size of solute particles $\propto \frac{1}{\text{solubility}}$.

(vi) Mechanical stirring

Mechanical stirring increases solubility. For example, sugar dissolves faster on stirring with a spoon.

The solubility of solids in liquids, however, remains unaffected by changes in pressure

Solubility curves

The graphs which show the variation of solubility with temperature are called solubility curves. With its help, solubility of any solute at a particular temperature can be find out.

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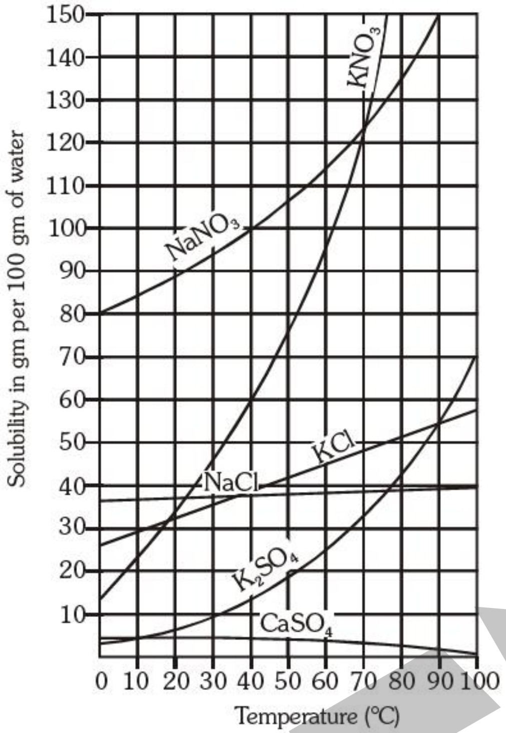

Graph between solubility and temperature

Solubility of gases in liquids

The gases are usually soluble in water as well in other solvents to a certain extent. The solubility of a gas in liquid depends on (i) nature of the gas, (ii) the pressure applied, (iii) temperature and (iv) the nature of the liquid which is taken as solvents.

The solubility of gas in liquid is defined as the mass of a gas dissolved in a given volume of a liquid at constant temperature is directly proportional to the pressure of the gas in equilibrium with the liquid. This is known as **Henry's law**

So, if m be the mass of gas dissolved per unit volume of a solvent at pressure P then,

$m \propto P$ at constant temperature

$m = KP$ where K is proportionality constant

In terms of mole fraction

$x = K_H P$

x – mole fraction of gas

P – partial pressure of gas over the solvent

The solubility of gases in liquids increases on decreasing the temperature or decreases on increasing the temperature. For example, water contains dissolved oxygen, when water is boiled, the solubility of oxygen in water decreases and the excess oxygen escapes in form of bubbles.

For example, In sea more water animal species are found in deep sea as dissolved oxygen is more.

The solubility of gases in liquids, however, increases on increasing the pressure and decreases on decreasing the pressure. For example, during manufacture of cold drinks, carbon dioxide is dissolved in water under pressure.

2.11 Suspension

A suspension is a heterogeneous mixture in which the solute particles do not dissolve but remain suspended throughout the bulk of the medium.

Please note that suspensions are formed by only those substances which are insoluble in water.

Note: Properties of suspensions are discussed in foundation module.

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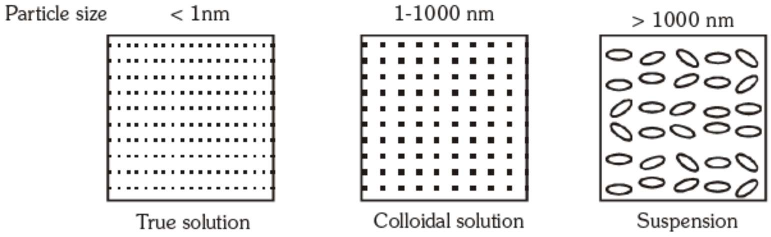
2.12 Colloidal solution

Solutions in which the size of the particles lies in between those of true solutions and suspensions are called colloidal solutions or simply colloids.



True solution   Colloidal solution   Suspension

Particle size of a true solution, a colloidal solution and a suspension.

Due to relatively smaller size of particles, these mixtures appear to be homogeneous but actually they are heterogeneous. Since the colloidal solutions are heterogeneous in nature, therefore, to distinguish them from true solutions, the term "sol" is used in place of solution.

Emulsions

Colloidal sols in which both the dispersed phase and the dispersion medium are liquids are called emulsions.

(i) Oil-in-water emulsions: In these emulsions, oil is the dispersed phase and water is the dispersion medium.

(ii) Water-in-oil emulsions: In these emulsions, water is the dispersed phase and oil is the dispersion medium.

These emulsions are usually prepared by shaking oil and water vigorously. However, these emulsions of two pure liquids all usually not stable.

The substances which are added to stabilize emulsions are called **emulsifiers** or **emulsifying agents**. These stabilize the sols by reducing the surface tension of water. For example, milk is oil-in-water type emulsion, in which liquid fat is dispersed in water and milk protein **lactalbumin** is the emulsifying agent

Applications of colloids in everyday life

Colloids play a very significant role in nature and in our daily life. Some of the important applications of colloids are discussed below:

(i) Medicines: Most of the medicines used are in the colloidal form because in this form, they are more easily assimilated due to large surface area and hence are more effective.

For example,

(a) Argyrol is a silver sol used as an eye lotion

(b) Colloidal antimony is used for curing kalazar.

(c) Colloidal gold is used as an intramuscular injection.

(d) Milk of magnesia, which is an emulsion, is used as an antacid for reducing acidity in the stomach.

(ii) Food articles: A number of food articles that we eat are colloidal in nature. For example, milk, butter, ice creams, fruit juices, halwa, etc.

(iii) Fog, mist and cloud: In winters, at night, the moisture of the air condenses on the surface of dust particles forming fine droplets. These droplets are colloidal in size and hence continue to float in the air in the form of fog or mist.

Clouds are aerosols consisting of small droplets of water suspended in the air. In the upper atmosphere where the temperature is low, they condense together to form bigger drops which come down in the form of rain. Rain is also caused when two oppositely charged clouds meet each other.

(iv) Artificial rain: Artificial rain can be caused by spraying electrified or oppositely charged colloidal dust, sand particles over a cloud. The colloidal water particles present in the cloud will get neutralized and coagulate to form bigger water drops causing artificial rain. Artificial rain can also be caused by throwing common salt on the clouds, as it is an electrolyte and brings about coagulation of water particles.

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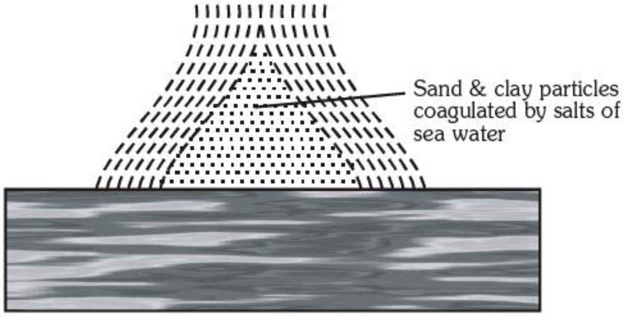
(v) Formation of Delta: River water contains charged colloidal particles of clay, sand and many other materials. Sea water is a very big store-house of a variety of electrolytes dissolved in it. As soon as river water comes in contact with sea water, the electrolytes present in sea water coagulate the suspended colloidal particles which ultimately settle down at the point of contact. Thus, the level of the river bed rises. As a result, water adopts a different course and delta is formed in due course of time.

It is so called because the heap formed has a shape similar to the Greek letter Δ (delta). In other words, (Δ) delta is formed due to silting of the estuary (i.e. deposit of sediment at the mouth of the river).



Formation of Delta

(vi) Blue colour of the sky: This is due to the scattering of light by colloidal dust particles present in air (Tyndall effect). This is explained by Rayleigh scattering according to which if diameter of particles is smaller than the wavelength of the incident radiation, scattering takes place. As blue colour of the white sunlight has minimum wavelength, it shows more intense scattering. Hence, sky looks blue.

Similarly, sea water looks blue due to scattering of light by the colloidal impurities present in sea water.

(vii) Tail of comets: It is seen as a Tyndall cone due to the scattering of light by the tiny solid particles left by the comet in its path.

(vii) Blood: It is a colloidal solution of an albuminoid and the bleeding stops on applying ferric chloride solution due to coagulation of blood forming a clot.

(ix) Cleansing action of soap: Soap solution is colloidal in nature. It removes the dirt particles either by adsorption or by emulsifying the greasy matter sticking to the cloth.

(x) Smoke screen: In warfare, smoke screens are used which are nothing but colloidal dispersion of certain substances (For example, titanium oxide) in the air.

2.13 Separation of mixtures

Many mixture contain useful substances mixed with unwanted materials. In order to obtain these useful substances, chemist often have to separate them from the impurities. Chemists have developed many different methods of separation. Use of method depends on what is in the mixture and the properties of substances. It also depends on whether the substance to be separated are solid, liquid or gas.

Separation of solid – solid mixtures

(1) Solvent extraction

In this method of separation, solubility of one component in a solvent is used. For example, a mixture of sulphur and sand can be separated by this method. Here sulphur is soluble in carbon disulphide (CS_2) and sand is insoluble.

(2) Magnetic separation

In this method of separation, magnetic property of one component is used. For example, mixture of iron ore and sand can be separated by this method. Here iron ore is attracted by magnet and sand is left behind.

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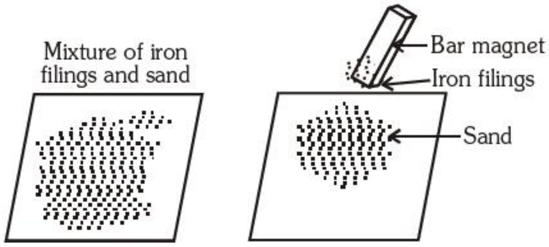


Separation of a mixture of iron filings and sand

(3) Gravity method

In this method of separation, difference in densities of component is used. For example, mixture of sand and chalk powder can be separated by this method. Here, sand being heavier than chalk powder sinks in water whereas chalk powder floats on water.

(4) Fractional crystallisation

In this method of separation, difference in solubility of the components in the same solvent is used. For example, mixture of potassium nitrate (KNO_3) and sodium chloride (NaCl) can be separated by this method. Here, potassium nitrate (KNO_3) being more soluble than sodium chloride (NaCl) in water, when the aqueous solution of this mixture is subjected to heating and subsequent cooling the more soluble potassium nitrate (KNO_3) remains in the solution, less soluble sodium chloride (NaCl) crystallizes out first.

CONCEPTUAL CHALLENGE 2.5

A mixture contains two components A and B. The solubilities of A and B in water near their boiling point are 10 grams per 100 ml and 2g per 100 ml respectively. How will you separate A and B from this mixture?

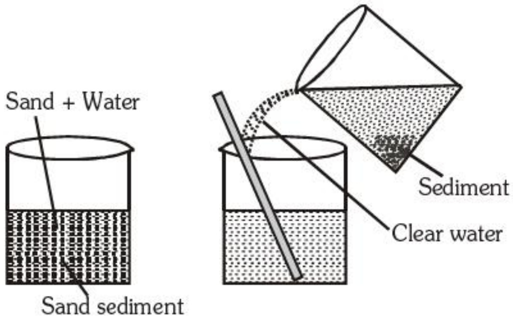
Explanation

Fractional crystallization. When the saturated hot solution of this mixture is allowed to cool, the less soluble component B crystallizes out first leaving the more soluble component A in the mother liquor.

Separation of solid - liquid mixtures

(1) Sedimentation and decantation

In this method of separation, high density of insoluble solid component is used. For example, mixture of sand and water can be separated by this method. Here sand being heavier settles at the bottom and liquid is slowly transferred into another container.



(a) Sedimentation (b) Decantation

(2) Filtration

The process of filtration is used to separate insoluble solid component of a mixture from the soluble component in a given solvent.

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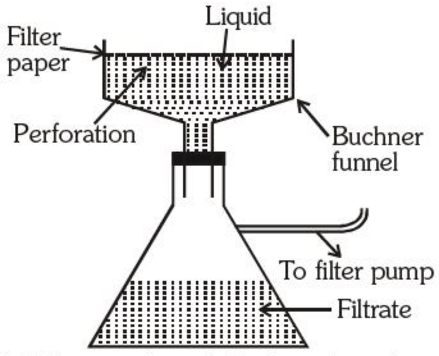
For example,

A mixture containing naphthalene and urea can be separated by this technique. Urea dissolves in water while naphthalene remains insoluble. Urea is recovered from the filtrate by evaporating water.

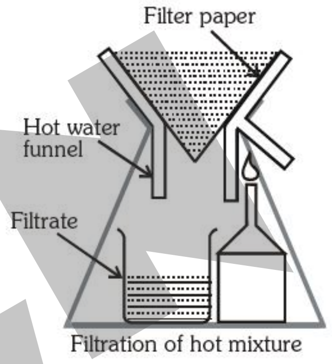


(a) Filtration through Buchner funnel

Sometime for separation purposes the filtration of a hot solution is required. For example, a mixture of anthracene and benzoic acid is separated by dissolving it in hot water and filtering the hot solution. Benzoic acid crystallizes on cooling while anthracene remains as an insoluble residue.

If the water soluble component of a mixture is appreciably soluble in hot water but only sparingly soluble in cold water, then to separate the mixture, filtration of a hot solution is required. This is carried out through a fluted filter paper to avoid crystallisation during filtration and also to remove suspend impurities. If the solution to be filtered is sufficiently large, then filtration is done through a 'hot water funnel' to avoid formation of crystals in the funnel and its stem. The jacket of the hot water funnel keeps the solution hot in the glass funnel placed in it.

For example, a mixture of anthracene and benzoic acid is separated by dissolving the mixture in hot water and filtering the hot solution.



(b) Filtration of hot mixture

Benzoic acid dissolves in hot water but anthrance does not. Upon filtration, anthracene remains as a residue on the filter paper while benzoic acid crystallises from the filtrate on cooling.

Sometimes, the filtration is very slow and takes a long time. In such cases, filtration is carried out under reduced pressure using a Buchner funnel and water suction pump are shown in figure below.

Separation of liquid – liquid mixture

(1) Vacuum distillation or distillation under reduced pressure

This technique of distillation is applied to liquids which decompose on heating to their boiling point. We know that the boiling point of a liquid varies with atmospheric pressure i.e., at reduced pressure the boiling point of liquid is also reduced and thus liquid distils at low temperature. For example, N_2 and Ar.

(2) Steam distillation

This is a convenient method for the separation and purification of organic compounds (solid or liquid) from non-volatile organic or inorganic impurities. This method is applicable to only those compounds which are volatile in steam, insoluble in water, possess a vapour pressure of about 10 - 15 mm of Hg at 373 K and contain non-volatile impurities. Some of the compounds which can be purified by this process are essential oils, nitrobenzene, chlorobenzene, etc.

CONCEPTUAL CHALLENGE 2.6

How will you separate a mixture of o-nitrophenol and p-nitrophenol?

Explanation

Steam distillation, o-nitrophenol being volatile distils over along with water while p-nitrophenol being non-volatile remains in the flask.

ALLEN

Separation of gas - gas mixtures

(1) Diffusion

In this method of separation, difference in densities of component gases is used. The gas with lower molecular weight diffuses faster than the gas with higher molecular weight. For example, hydrogen (H_2) and methane (CH_4), helium (He) and sulphur dioxide (SO_2).

(2) Dissolution in suitable solvents

In this method of separation, difference in solubility of component gases in a given solvent is used. For example, a mixture of carbon dioxide (CO_2) is soluble in potassium hydroxide (KOH) leaving behind carbon monoxide (CO). Here, in a mixture of ammonia (NH_3) and nitrogen (N_2) ammonia (NH_3) is soluble in water and nitrogen (N_2) is insoluble.

(3) Preferential liquefaction

In this method of separation, difference in liquefaction of component gases in a given solvent is used. For example, a mixture of ammonia (NH_3) and hydrogen (H_2) can be separated by this method. Here, ammonia gets liquefied under high pressure and hydrogen gas is left behind.

(4) Fractional evaporation

In this method of separation difference in boiling points of the component gases is used. For example, when air is liquefied, the major components of air, nitrogen (N_2) and oxygen (O_2) can be separated by subjecting the liquid to evaporation. Here, nitrogen (N_2) has a lower boiling point and hence boils off, oxygen (O_2) has a higher boiling point and remains behind.

Separation of liquid - gas mixtures

(1) **Heating:** In this method of separation, decrease in solubility of a gas with increase in temperature is used. For example, when a solution containing a gas is subjected to slight heating below the boiling point of the liquid, the gas escapes out leaving behind the liquid component. For example, separation of dissolved oxygen (O_2) in water by heating water.

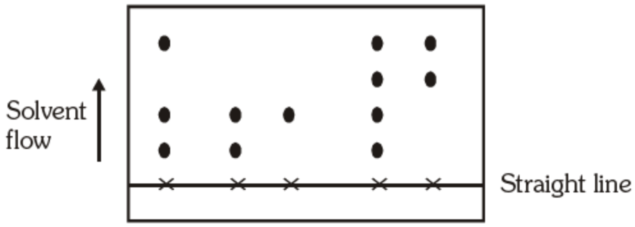
(2) **Lowering the pressure:** In this method of separation, difference in solubility of gas in the liquid at different pressure is used. For example, soda water can be separated by this method. Here, when soda water bottle is opened, the pressure inside the bottle decreases and carbon dioxide (CO_2) gas fizzes out of the bottle.

A special method applicable for all types of mixture is

Chromatography:

The name chromatography is based on the Greek word chroma, for colour since the method was first used for the separation of coloured substances found in plants.

Ex. The given chromatogram was prepared using spots of five different inks:



How many different types of dyes were used to make these five inks?

(1) 3 (2) 5 (3) 4 (4) 10

CONCEPTUAL CHALLENGE 2.7

Name the method which is most suitable for separation of the following:

(a) Oxygen from liquid air

(b) Red blood cell from plasma

(c) Petrol and kerosene from crude oil

(d) Coffee grains from coffee solution

(e) Pieces of steel from engine oil

(f) Amino acids from fruit juice solution

(g) Ethanol and either

Explanation

(a) Oxygen from liquid air = Fractional distillation

(b) Red blood cell from plasma = Centrifugation

(c) Petrol and Kerosene from crude oil = Fractional distillation

(d) Coffee grain from coffee solution = Filtration

(e) Pieces of steel from engine oil = Magnetic separation

(f) Amino acids from fruit juice solution = Chromatography

(g) Ethanol and ether = Fractional distillation

ALLEN

EXERCISE

1. The most abundant metal in the earth's crust is

(1) Fe
(2) Cu
(3) Al
(4) Au

2. The most abundant element in the earth's crust is

(1) Si
(2) C
(3) O
(4) Ca

3. Air is regarded as a mixture because

(1) its pressure may very.
(2) its temperature may change.
(3) its volume changes under different conditions.
(4) its composition may vary.

4. Which of the following is not true about mixtures?

(1) Mixtures can be homogeneous or heterogeneous.
(2) Components in a mixture are always present in a fixed ratio.
(3) Properties of a mixture are the average of its components.
(4) Components of a mixture can be separated easily by simple physical methods.

5. Which of these is not a mixture?

(1) Oil and water
(2) Sand and water
(3) Diet Soda
(4) All are mixtures.

6. A sample contains two substances and does not have uniform properties. The sample is,

(1) a compound
(2) a heterogeneous mixture
(3) an element
(4) a homogeneous mixture

7. Which of the following is a homogeneous system?

(1) Muddy water
(2) Bread
(3) Concrete
(4) A solution of sugar in water

8. Select the odd one out.

(1) Hydrogen
(2) Oxygen
(3) Steam
(4) Chlorine

9. A homogeneous system among the following is

(1) milk
(2) sand in water
(3) urea in water
(4) benzene in water

10. Which of the following is insoluble in water?

(1) Benzene
(2) Alcohol
(3) Acetic acid
(4) Sugar

11. Which of the following is a compound?

(1) Stainless steel
(2) Bronze
(3) Graphite
(4) Hydrogen sulphide

12. Two substances A and B when brought together form a substance C with the evolution of heat. The properties of C are entirely different from those of A and B. The substance C is

(1) a compound
(2) an element
(3) a mixture
(4) none of these

13. Which of the following is a characteristic of both mixtures and compounds?

(1) They contain components in fixed proportions.
(2) Their properties are the same as those of their components.
(3) Their weight equals the sum of the weights of their components.
(4) Energy is given out when they are being prepared.

ALLEN

14. Which of the following is true solution?

(1) Milk (2) Chalk powder in water

(3) Salt solution (4) Blood

15. Solutions with low concentration of solutes are,

(1) concentrated (2) dilute (3) solvents (4) none of these

16. A liquid and a solid together consisting a single phase is known as

(1) solution (2) solute (3) solvent (4) emulsion

17. Amalgam is a solution of

(1) solid in solid (2) solid in liquid (3) liquid in solid (4) liquid in liquid

18. Which of the following is a true solution?

(1) NaCl in sulphur dioxide (2) Copper in silver

(3) Salt in petrol (4) Mud in water

19. A solution of iodine in alcohol is known as

(1) aqueous solution. (2) alcoholic solution.

(3) heterogeneous solution. (4) tincture of iodine.

20. Solution consists of

(1) solvent (2) solute (3) solutes (4) all of these

21. Solution is a

(1) homogeneous mixture.

(2) heterogeneous mixture.

(3) compound formed between solute and solvent.

(4) homo as well as heterogeneous mixture.

22. Solid solution is

(1) Solid in solid (2) Solid in liquid (3) Solid in gas (4) Liquid in solid

23. The solution of sugar in water contains

(1) free atoms. (2) free ions.

(3) free molecules. (4) free atoms and molecules.

24. Gun powder is a _____.

(1) solid-liquid homogeneous mixture (2) solid-liquid heterogeneous mixture

(3) solid-solid homogeneous mixture (4) solid-solid heterogeneous mixture

25. Which of the following is not a solution?

(1) Smoke (2) Air (3) Salt (4) A gold ring

26. When raisin is placed in water it

(1) shrinks (2) swells (3) burns (4) remains same

27. Out of formality (F), molality(m), molarity(M) and mole fraction(x), which is/are independent in temperature

(1) M, m (2) F, x (3) m, x (4) M, x

ALLEN

28. If 100 ml of 1M NaOH is diluted to one litre, the resulting solution has molarity

(1) M/100 (2) 0.1 M (3) 1 M (4) 10 M

29. What is the volume of water to be added to 200 ml of 18 M H_2SO_4 solution to get 1.8 M H_2SO_4 solution?

(1) 1800 litres (2) 2000 litres (3) 2000 ml (4) 1800 ml

30. The molarity of a solution prepared by dissolving 7.1 gm of Na_2SO_4 in 100 ml water is

(1) 2 M (2) 1 M (3) 0.5 M (4) 0.05 M

31. One molal solution contains

(1) one mole of solute in one litre of solution.
(2) one mole of solute in 1000 gm of the solvent.
(3) one gram-equivalent in 1000 ml of solutions.
(4) one gram-equivalent in 1000 gm if solvent.

32. The number of moles of NaOH present in 10 litres of 1 molar solution is

(1) 10 (2) 1 (3) 0.1 (4) 0.01

33. How many moles are represented by 24.5 gm of H_2SO_4?

(1) 2.5 (2) 2.05 (3) 0.25 (4) 25

34. Which of the following acid has the same molecular weight and equivalent weight?

(1) H_3PO_2 (2) H_3PO_3 (3) H_3PO_4 (4) H_2SO_4

35. Find the number of equivalents of solute present in 123 ml of 1 N KOH solution.

(1) 123 (2) 12.3 (3) 1.23 (4) 0.123

36. 1000 ml of water is added to 250 ml of 0.05 N HCl solution. Find the normality of dilute solution.

(1) 1 N (2) 0.05 N (3) 0.01 N (4) 5 N

37. The molarity of H_3PO_4 solution is 0.05 M. Find its normality.

(1) 0.15 N (2) 1.5 N (3) 0.03 N (4) 0.3 N

38. A one molar solution is one that contains

(1) 1 g of the solute in 1000 g of solvent.
(2) 1 g mole of solute in 1000 ml of solution.
(3) 1 g mole of solute in 22.4 litres of solution.
(4) 1 g mole of solute in 1000 g of solvent.

39. 4 gm of NaOH are dissolved in 500 ml of water. Active mass of NaOH is

(1) 0.1 (2) 0.2 (3) 0.3 (4) 0.4

40. Which is dimensionless quantity?

(1) Molarity (2) Mole fraction (3) Normality (4) None of these

41. Concentrated Hydrochloric Acid is 36.5% by weight. What is the molality of the solution?

(1) 1.575 molal (2) 15.75 molal (3) 157.5 molal (4) 1575 molal

42. The concentration unit which changes with temperature is

(1) molarity
(2) molality
(3) mole Fraction
(4) both molality and mole fraction

43. To change the molal concentration to one half which one of the following should be adopted?

(1) Weight of solute should be doubled.
(2) Weight of solvent should be doubled.
(3) Volume of solvent should be doubled.
(4) Weight of the solution should be doubled.

ALLEN

44. The concentration method applicable to solutes with macro molecules, polymers and ionic solid is

(1) molarity (2) formality (3) normality (4) molality

45. 3.65 grams of HCl is dissolved in 180 grams of water. What is the Mole Fraction of water and HCl?

(1) 1 and 9 (2) 9 and 1 (3) .99 and .009 (4) 0.9 and 0.1

46. Molarity is expressed in

(1) moles/kg (2) g/lit (3) moles/lit (4) lit/mole

47. The ratio between the number of moles of a compound and total number of moles present in a mixture is called

(1) normality (2) molarity (3) mole fraction (4) formality

48. The unit of mole fraction of a component of a solution is

(1) Moles/litre (2) Moles/Kg (3) No units (4) Grams/litre

49. 9.8 g of H_2SO_4 is present in 2 litres of a solution. The molarity of the solution is

(1) 0.1 M (2) 0.05 M (3) 0.01 M (4) 0.5 M

50. Molarity of a solution that contains 49 g H_3PO_4 in 2 litres of solution is

(1) 0.25 (2) 0.5 (3) 0.75 (4) 1.0

51. How much water is added to 10 ml of 10 N HNO_3 to make its conc. 0.1 N?

(1) 100 ml (2) 1010 ml (3) 990 ml (4) 1000 ml

52. What is the solubility of sucrose sugar, $C_{12}H_{22}O_{11}$, at 20°C?

(1) 55g/100 g water (2) 75 g/100 g water

(3) 90 g/100 g water (4) 204 g/100 g water

53. What is the mass of a 10.0% blood plasma solution that contains 2.50 g of dissolved solute?

(1) 0.250 g (2) 0.278 g (3) 25.0 g (4) 250 g

54. What is the mass of water needed to prepare 5.00 kg of a 40.0% antifreeze solution?

(1) 2.00 kg (2) 3.00 kg (3) 3.33 kg (4) 12.5 kg

55. When salt is dissolved in water, there is

(1) an increase of boiling point. (2) no change in boiling point.

(3) a decrease of boiling point. (4) none of these

56. Solubility of deliquescent substances in water generally

(1) High (2) Modulate (3) Low (4) Cannot be said

57. Coca-Cola is carbonated by injecting the liquid with carbon dioxide gas. Under what conditions is the solubility of carbon dioxide the greatest?

(1) Low temperature, low pressure (2) Low temperature, high pressure

(3) Low temperature, pressure is not a factor (4) High pressure, temperature is not a factor

58. Which of the following illustrates the like dissolves like rule for two liquids?

(1) A polar solvent is insoluble in a polar solvent.

(2) A polar solvent is soluble in a nonpolar solvent.

(3) A nonpolar solvent is soluble in a nonpolar solvent.

(4) All of these

ALLEN

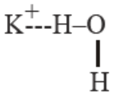
59. Apply the like dissolves like rule to predict which of the following liquids is miscible with water.

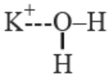
(1) chloroform,$CHCl_3$
(2) glycerin,$C_3H_5(OH)_3$
(3) toluene,$C_6H_5CH_3$
(4) All of the above

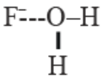
60. Grease spots from garments can be separated by a method of

(1) chromatography
(2) solvent extraction
(3) sublimation
(4) dissolution in suitable solvents

61. When solid potassium fluoride dissolves in water, which of the following is one of the aqueous ions formed?

(1) 
$\overset{+}{K}$---H–O with H below O

(2) 
$\overset{+}{K}$---O–H with H below O

(3) 
$\overset{-}{F}$---O–H with H below O

(4) all of these

62. Which of the following increases the rate of dissolving for a solid solute in a solvent?

(1) Grinding the solute
(2) Heating the solution
(3) Stirring the solution
(4) All of these

63. The type of emulsion is mentioned against the emulsion in each of the following. Which is not correctly matched?

(1) Milk: o/w
(2) Shampoo: w/o
(3) Butter: w/o
(4) Cold cream: w/o

64. The emulsifying agent present in milk that makes it stable is

(1) lactose
(2) maltose
(3) casein
(4) lactalbumin

65. Which of the following is Aerosols?

(1) Alloy
(2) Fog
(3) Milk
(4) Butter

66. A mixture of ethanol and water can be separated by

(1) filtration
(2) decantation
(3) fractional distillation
(4) sublimation

67. Which of the following is incorrectly matched?

(1) Butter-sol
(2) Milk-emulsion
(3) Fog emulsion
(4) Pearls-Solid sol

68. After crystallization takes place, the solution in contact with the crystal is

(1) concentrated
(2) unsaturated
(3) saturated
(4) supersaturated

69. Which one of the following is correctly matched?

(1) Emulsion-curd
(2) Foam-mist
(3) Aerosol-smoke
(4) Solid sol-cake

70. The zig-zag movement of dispersed phase particle in a colloidal system is known as

(1) transitional motion
(2) circular motion
(3) linear motion
(4) brownian motion

71. Scattering of light takes place in

(1) electrolytic solutions
(2) colloidal solutions
(3) suspension
(4) electroplating

72. Which of the following forms a colloidal solution in water?

(1) Salt
(2) Glucose
(3) Starch
(4) Barium nitrate

73. Ice cream is an example of

(1) true solution
(2) compound
(3) colloid
(4) suspension

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74. Adsorption property is applied in

(1) sewage disposal (2) ultramicroscope (3) smoke precipitator (4) medicine

75. Solid foam is

(1) solid dispersed in solid (2) liquid dispersed in solid

(3) gas dispersed in solid (4) solid dispersed in liquid

76. The dispersed phase constitutes

(1) solvent (2) solute (3) solution (4) mixture of solvent

77. Mixture of $ZnCl_2$ and $PbCl_2$ can be separated by

(1) distillation (2) crystallisation (3) sublimation (4) adding acetic acid

78. The process used to separate oil and water is

(1) distillation (2) sublimation

(3) separating funnel (4) chromatography

79. Which of the following shows 'Tyndall effect'?

(1) Salt solution (2) Starch solution (3) $CuSO_4$ solution (4) NaOH solution

80. Medicines from blood can be detected and separated by __________.

(1) filtration (2) chromatography (3) sublimation (4) centrifugation

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ANSWERS

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	3	3	4	2	4	2	4	3	3	1	4	1	3	3	2	1	2	2	4	4
Que.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	1	1	3	4	3	2	3	2	4	3	2	1	3	1	4	3	1	2	2	2
Que.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	2	1	2	2	3	3	3	3	2	1	3	4	3	2	1	1	2	3	2	2
Que.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	2	4	2	4	2	3	3	3	3	4	2	3	3	3	3	2	2	3	2	2